IEEE P802.15 Working Group for Wireless Personal Area Networks

Performance Metrics of MAC Coexistence Evaluation

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Outline

- MAC performance metrics definition
  - Access delay
  - Throughput
  - Goodput
  - Packet loss
- Coexistence performance metrics:
  - compare each specification against itself.
  - difference of two independent sample means: one-tailed hypothesis test.
- Where to measure?
- Measurement format

Access Delay

- Objective:measure the time it takes to transmit a packet from the time it is passed to the MAC layer until it is successfully received at the destination (MAC layer).
- Definition:
  - average access delay: sum of all access delays divided by the number of samples. (Units = milliseconds)
  - coefficient of delay variance: access delay standard deviation divided by the average access delay.
  - access delay probability distribution function (95th, 99th percentiles).

Throughput

- Objective: measure the number of bits per second delivered over the medium. This measure includes both packet payload and headers.
- Definition:
  – average throughput: total number of bits received at the destination divided by the simulation time.Units: Mbits/s.

Goodput

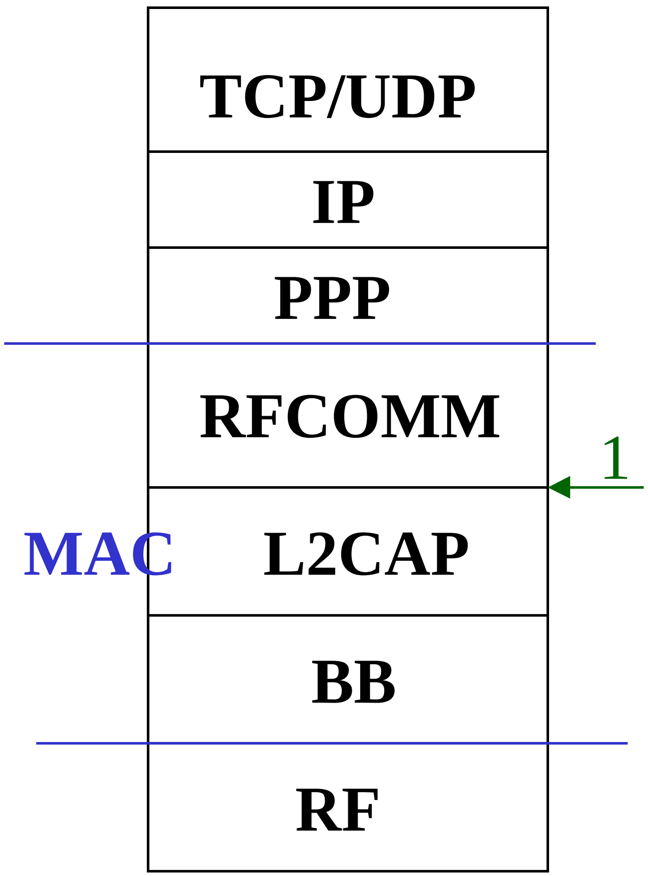
- Objective: measure the number of bits of information delivered over the medium. This measure does not include neither packet headers nor overheads. This may be useful for measuring the performance of higher layer traffic.
- Definition:
  - average goodput: total number of information bits received at the destination divided by the simulation time. Units: Mbits/s

Packet Loss

- Objective: measure the number of packets discarded at the MAC layer due to errors in the bit stream. This measure is conducted after performing error correction (FEC, HEC).
- Definition:
  - packet loss: number of packets lost divided by the total number of packets sent during the simulation time. Units:%

Where to measure the MAC layer performance?

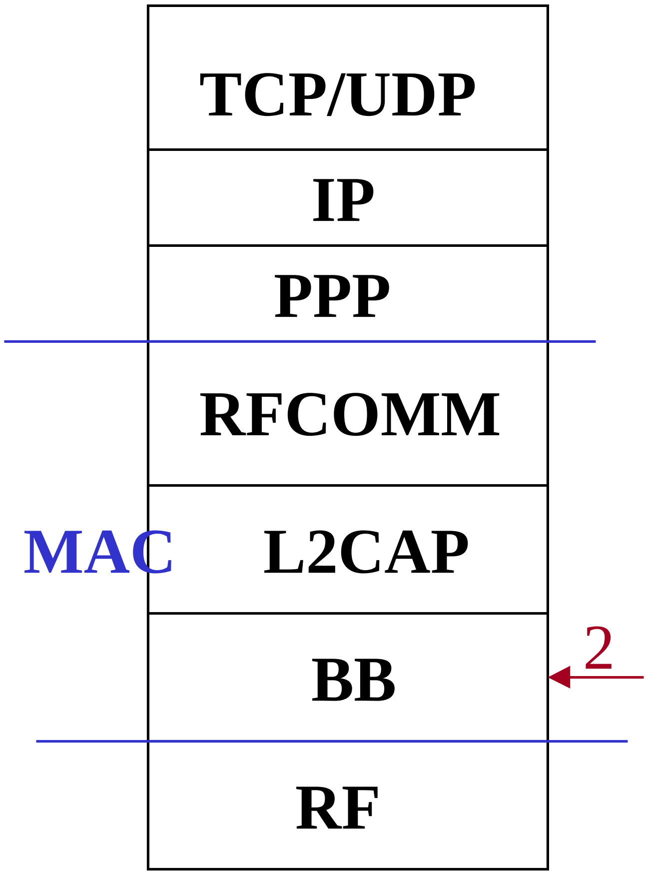
Example: Bluetooth LAN Access data traffic flow



- Access delay is computed after the reassembly of DM3 and DM5 packets into an L2CAP packet and may include retransmission time due to ARQ.
- HEC, FEC and CRC are performed on the DM5 and DM3 packets received.
- Throughput includes L2CAP overhead.
- Goodput includes L2CAP payload only and higher layer overheads.

Where to measure the MAC layer performance?

Example: Bluetooth LAN Access data traffic flow



- Access delay is computed upon the arrival of baseband packets containing DM3 and DM5 packets. Therefore the access delay does not account for any retransmission time.
- No HEC, FEC and CRC are performed.
- Throughput includes L2CAP, DM5/DM3 and baseband packet overheads.
- Goodput consists of the transmission of DM5/DM3 packets.

Summary of Advantages

- Baseband Measurements:
  - Consistent for different profiles, traffic types and channels since all have to use the baseband layer but not necessarily the L2CAP layer.
- L2CAP Measurements :
  - Accounts for effect of error correction algorithms (FEC, HEC and CRC) and retransmission delays and therefore may give better insights on the impact of interference onto higher layers.

Consensus

- Use L2CAP measurements for:
  - Access delay (mean, percentile, CDV)
  - Throughput, goodput
- Use baseband measurements for:
  - Packet loss

Measurement Format

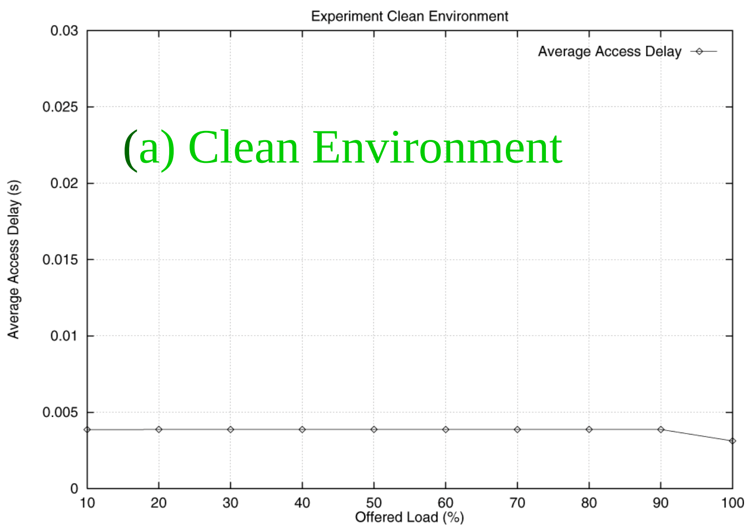
- Use either the offered load * or the BER on the x-axis to plot the i) access delay, ii) throughput, iii) goodput, iv) coefficient of delay variation, and v) packet loss on the y-axis.

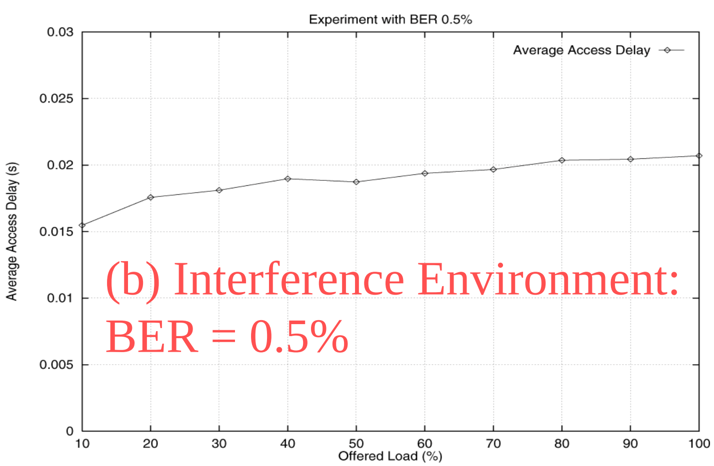
Note: the offered load measures the amount traffic sent as a percentage of the total capacity of the channel. Units: %

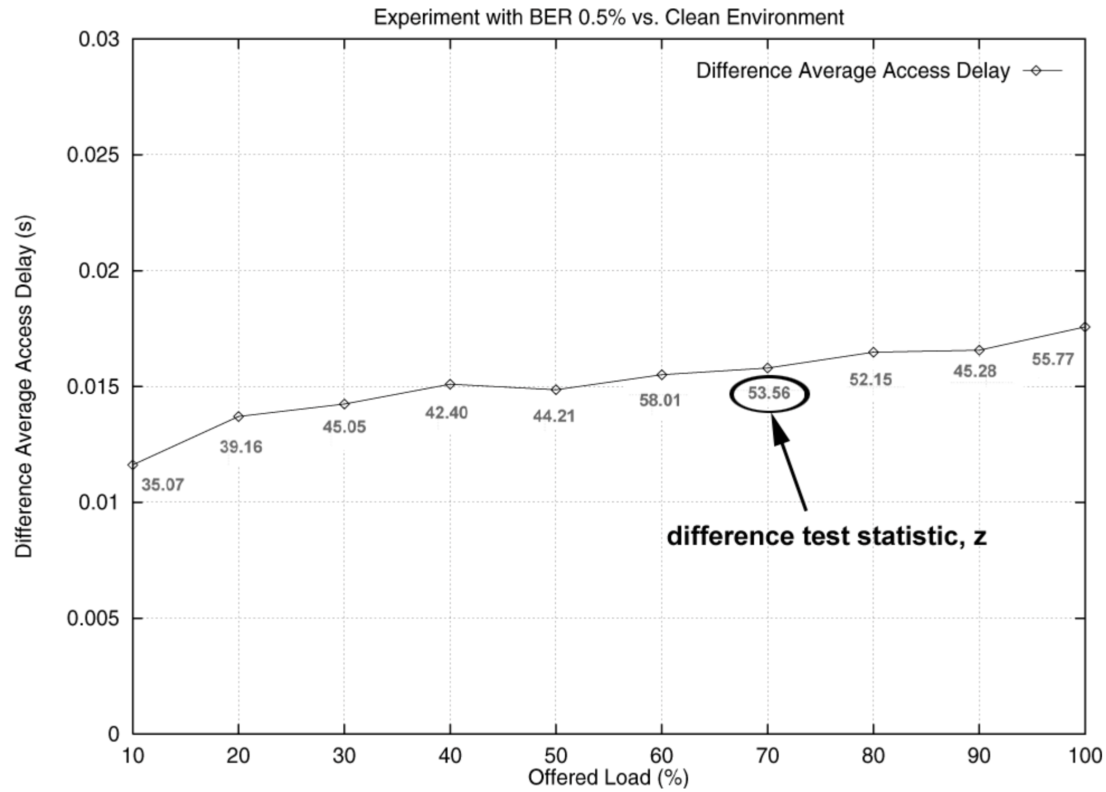
Measurement Methodology

- For every test scenario consisting of a specific network topology (number of devices, distance), and applications (voice, data):
  - obtain performance results for each protocol specifications (IEEE 802.11, Bluetooth) in
    - (a) a clean environment (without interference)
    - (b) a coexistence environment (with the interference effect).
  - compare results from (a) and (b): compute the difference and conduct a one tailed-test on the significance of the difference.

Measurement Example







Difference Measurement

Statistics Background *

- Comparison of two population sets:
  - how significant is the difference of two means?
- One-tailed test with significance level α

* Reference

- T.W. Anderson and J.D. Finn, “The New Statistical Analysis of Data”, Springer-Verlag, New York, Inc. 1996.

Difference of Two Means

- The average access delay in a coexistence environment (with interference) may be higher than the average access delay in a homogeneous environment ("clean") but there may be considerable overlap between the two sets of measurements. Therefore the difference obtained may not be meaningful.
- The question is:

How significant is the difference in access delay?

One-Tailed Test

- Assume that $H_0 : \mu_1 - \mu_2 \le 0$ (Null Hypothesis) and $H_1 : \mu_1 > \mu_2$ (Alternative)
- Compute a test statistic, z:

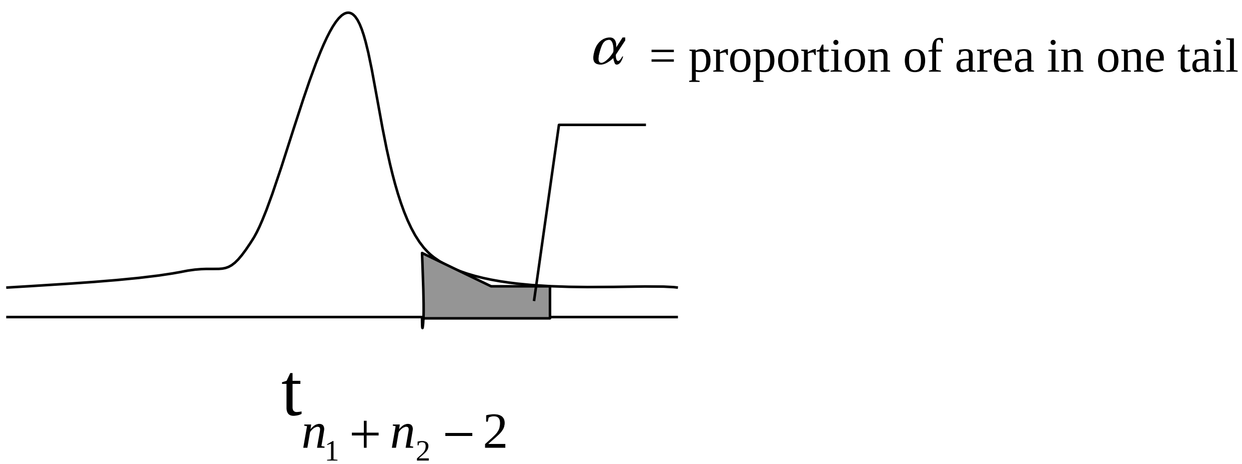
$$z = \frac{\overline{x}_1 - \overline{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

where $\overline{x}_1$ and $\overline{x}_2$ are the means and s_1^2 and s_2^2 are the variances; n_1 and n_2 are the sample sizes.

Hypothesis Test Procedure

- For a given significance level α = 10%. Use a t-distribution with f = $n_1 + n_2 - 2$ degrees of freedom to reject or accept H_0 .

f	α =0.1
1	3.078
2	1.886
3	1.638
4	1.533
..	
30	1.310
40	1.303
120	1.289
inf	1.282



If z > 1.303 for f = 40 and α = 10% then H_0 is rejected and H_1 is accepted. The significance level of the difference is at least 10%.